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Subject: Submittal of APP-GW-GLR-137, Revision 1"Bases of Digital Overpower and Over-Temperature Delta-T (OPΔT/OTΔT) Reactor Trips"

Westinghouse is submitting document APP-GW-GLR-137, Revision 1"Bases of Digital Overpower and Over-Temperature Delta-T (OPΔT/OTΔT) Reactor Trips" (Non-Proprietary). This report is submitted in support of the AP1000® Design Certification Amendment Application (Docket No. 52-006). The information provided in this report is generic and is expected to apply to all Combined Operating License (COL) applicants referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

This submittal addresses the below listed Confirmatory Items as indentified in the Advanced Final Safety Evaluation for Chapter 7 Titled "Instrumentation and Controls," of NUREG-1793, Supplement 2 - AP1000 Design Certification Amendment.

Confirmatory Items
- CI-SRP-7A-SRSB-01
- CI-SRP-7A-SRSB-02
- CI-SRP-7A-SRSB-04

Questions or requests for additional information related to the content and preparation of these documents should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

R. F. Ziesing
Director, US Licensing

/Enclosure

1. APP-GW-GLR-137, Revision 1, "Bases of Digital Overpower and Over-Temperature Delta-T (OPΔT/OTΔT) Reactor Trips"

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ENCLOSURE 1

APP-GW-GLR-137

Revision 1

"Bases of Digital Overpower and Over-Temperature Delta-T (OPΔT/OTΔT) Reactor Trips"

(Non-Proprietary)

Document Number: APP-GW-GLR-137 **Revision Number:** 1
Title: Bases of Digital Overpower and Overtemperature Delta-T (OPDT/OTDT) Reactor Trips

AP1000 Standard Combined License Technical Report

Bases of Digital Overpower and Overtemperature Delta-T (OPΔT/ OTΔT) Reactor Trips

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REV.	**CHANGES FROM PREVIOUS REVISION**
0	Original Issue
1	APP-GW-GLR-137 is revised to Revision 1 to reflect the clarifications of OI-SRP16-CTSB-42. • Updated report form to the newest revision – Cover page • Updated the header revision number to 1 – Header of all pages • Updated WEC address and copyright date – page 2 of 14 • Updated Table of Contents' page numbering – page 3 of 14 • Added a revision log to the document – page 3 of 14 • Made editorial/clarifying/formatting changes to the wording of items 2, 3 & 5 of Section 3.0 – pages 8 and 9 of 14 • Made editorial/clarifying/formatting changes – page 11 of 14 • Made formatting changes to references 1, 2, 4, and 5. Also, the note for reference 4 has been deleted and the Revision of reference 3 has been updated – page 14 of 14

1.0 INTRODUCTION AND SUMMARY

Operating Westinghouse pressurized water reactors (W-PWRs) use the Overpower Delta-T and Overtemperature Delta-T (OPΔT/OTΔT) reactor trips to protect the specified acceptable fuel design limits. These reactor trips are based on analog technology using the reactor vessel average temperature (T_{avg}) and ΔT signals (derived from hot leg and cold leg temperatures T_{hot} and T_{cold}), as documented in WCAP-8745-P-A (Ref. 1). Westinghouse is upgrading this analog technology to digital technology as part of the reactor protection system for the AP1000.

The purpose of this report is to describe the commonality of design bases and analytical methods as well as the differences in detailed implementation between the analog design (with OTΔT setpoint based on T_{avg}) and the digital design (with OTΔT setpoint based on core inlet temperature).

The digital OPΔT/OTΔT design provides the following improved features important to safety compared to the analog design:

1. Simpler and more direct conversion of the core thermal design limits to protection system setpoints;
2. Improved monitoring of thermal power and protection system performance;
3. Simplified dynamic compensation;
4. Monitoring and prevention of local hot leg saturation conditions that could invalidate core thermal power measurement; and
5. Provision for reactor trip on high core inlet temperature if desired.

These features are discussed below.

The analog formulation for the OPΔT/OTΔT reactor trips dates from 1966-68 when it was first applied to W-PWRs. At that time, a novel design was proposed to minimize errors in measuring ΔT. To eliminate the errors in obtaining an absolute temperature for T_{hot} and T_{cold} and then subtracting (thus adding the individual errors in measuring T_{hot} and T_{cold}), a four-RTD bridge was proposed. With two hot leg RTDs and two cold leg RTDs, ΔT would be obtained directly across two points of the bridge and T_{avg} obtained across the other two points. That design was soon obsolete as a result of (a) improvements in instrumentation and (b) discovery that errors caused by hot leg streaming were large compared to instrument measurement errors. However, the use of T_{avg} and ΔT was already frozen into the protection system design despite the fact that the core thermal design limits are computed as functions of core inlet temperature (T_{inlet}) and power.

With improved instrumentation for converting RTD resistance to temperature signals, higher protection system accuracy is obtained by measuring T_{cold} and T_{hot} directly. Thus, the OTΔT equation can be rearranged so that the setpoint is computed as a function of T_{cold} rather than as a function of T_{avg}. With the advent of digital systems, the core thermal power can be more accurately calculated than with the approximations inherent in using a ΔT signal. Thus, the ΔT power signal uses T_{hot}, T_{cold}, and pressurizer pressure to compute cold leg density and hot leg and cold leg enthalpies. This is directly analogous to the ΔT signal but is a much more accurate measure of core thermal power.

The conversion of T_{inlet} and power to T_{avg} and ΔT is a non-trivial process considering the non-linearities in the density and heat capacity of water. (For example, see Appendix B of Ref. 1.) However, the relation between the protection system setpoints and the core thermal design limits is unchanged. The core thermal design limits and their relation to OPΔT/OTΔT setpoints is described further in Section 2.

Since conversion to T_{avg} and ΔT is eliminated, the digital OPΔT and OTΔT reactor trip formulation substantially simplifies converting the core thermal design limits (which remain unchanged from those described in WCAP-8745-P-A) to reactor trip setpoints.

The ΔT power signal (described in Section 3) can be directly compared to the measured calorimetric power, and thereby makes it easier to monitor and trend errors. No correction for RCS temperature, pressure, or power level is needed. This enhances monitoring capability of both the protection system performance and thermal power.

Direct use of T_{hot} and T_{cold} instead of T_{avg} and ΔT also simplifies the dynamic compensation for instrument delays and fluid transport time from the cold leg RTD to the core (to adjust for the difference between T_{inlet} and measured T_{cold}), and from the core to the hot leg RTD. The dynamic compensation needs to account for the time difference in each independent signal.

Hot leg boiling is a measurement limit rather than a safety limit. (Section 2-4 of Ref. 1 specifically notes that hot leg boiling is not a core protection limit.) As is now well known, hot leg streaming can cause large variations between local hot leg temperatures. Hence, one RTD could approach saturation—and thus become invalid for measurement—well before the bulk fluid in the hot leg approaches saturation. (In the majority of operating W-PWRs, and also in the AP1000 design, the temperature signals from three separate RTDs, located approximately 120° apart around the hot leg circumference, are combined to obtain a hot leg temperature signal in each protection system division.) The digital design permits setting an individual RTD temperature signal to vote for a trip if it approaches saturation. (See the discussion in Section 3.) This eliminates the need to assign uncertainties to the variation between local RTD temperature and bulk hot leg fluid temperature. This feature also removes the dependency (discussed in Appendix B of Ref. 1) of the analog OTΔT trip on the steamline safety valves to protect against hot leg saturation.

The OTΔT trip setpoint is interpolated from a table of the thermal design limits that define allowable power versus T_{inlet} at various pressures. This table, if desired, can specify zero allowable power if inlet temperature rises above a specified value—in effect a reactor trip on high inlet temperature. This feature can be used to back up other trips for additional defense in depth, or to exclude other undesirable operating conditions.

A version of the digital OPΔT/OTΔT trip was installed in the Temelin nuclear station (two 1000-MWe units) in the Czech Republic, and has been operating satisfactorily since Unit 1 criticality in 2000.

In summary, the digital OPΔT/OTΔT reactor trip design has differences in implementation that benefit safety. However, neither the basis nor the measured parameters are changed from the analog design.

2.0 BASES FOR THERMAL PROTECTION

The design bases for the reactor thermal protection remain unchanged from those documented in Section 2.3 of WCAP-9272-P-A (Ref. 2). The purpose of the OPΔT reactor trip continues to be to prevent fuel centerline melt due to excessive linear heat generation rates as measured in kilowatts per foot (kW/ft). The limitations of the digital OPΔT trip (e.g., speed of transient and range of pressure and flow) are unchanged from the analog OPΔT as described in Ref. 1. The fuel-temperature design basis is to preclude fuel melting (with 95% probability at the 95% confidence level) for the peak kW/ft fuel rod during normal operation and anticipated operational occurrences (Design Conditions I and II as defined in ANSI/ANS-N18.2/1973, Ref. 5). The AP1000 kW/ft limit for preventing fuel centerline melt is described in Section 4.4.1.2 of the Design Control Document (DCD, Ref. 3).

The purpose of the OTΔT reactor trip continues to be to prevent departure from nucleate boiling (DNB) (Section 2.3 of Ref. 2). The limitations of the digital OTΔT trip (e.g., speed of transient and range of pressure and flow) are unchanged from the analog OTΔT trip as described in Ref. 1. The fuel DNB design basis, as documented in Section 2.3 of Ref. 2, is to preclude DNB (with 95% probability at the 95% confidence level) for the limiting fuel rods during normal operation and anticipated operational occurrences (Design Conditions I and II as defined in Ref. 5). The DNB design basis is reflected in the 95/95 limit of Departure from Nucleate Boiling Ratio (DNBR) as specified by a DNB correlation applicable to the fuel design. The DNB correlation and its design limits for AP1000 application are described in Section 4.4.1.1 of Ref. 3.

With respect to the OTΔT $f_1(\Delta I)$ and OPΔT $f_2(\Delta I)$ penalty functions, the protection system instrumentation design for all operating W-PWRs with OPΔT/OTΔT trip includes a signal of axial flux difference, ΔI, to generate reductions in the OPΔT and OTΔT trip setpoints. That continues to be the case with the digital OPΔT/OTΔT design, with the only difference being that the trip setpoint is the ΔT power signal instead of ΔT. The shape of the penalty function (zero if ΔI is within a deadband range, then a linear increase if ΔI increases outside that range) is also unchanged. The f(ΔI) functions result in more restrictive trip setpoints to account for power distributions in the core potentially more adverse to the design bases than the reference power distribution used for generating the core thermal design limits.

The thermal design limits are typically referred to as Safety Limits in Section 2.1.1 of the plant Technical Specifications, with specific values specified in the Core Operating Limits Report (COLR); and are generated as described in Section 4.3.5 of Ref. 2. As described in that reference, the DNB thermal limits represent the locus of points of core thermal power, primary system pressure, and reactor coolant inlet temperature which ensure that the DNB design basis is satisfied for the reference power shape. The DNBR methodology for generating the thermal limits is the same for either the analog OTΔT trip or the digital OTΔT trip. The DNBR methodology for AP1000 application is described in Sections 4.4.1.1.2 and 4.4.2.2 of Ref. 3.

Because DNBR calculations are based on the T_{inlet} and not T_{avg}, conversion to reactor trip setpoints is much simpler for the digital OTΔT trip than with the analog OTΔT trip based on T_{avg}. With the digital OTΔT trip, conversion of the core DNB limits to OTΔT setpoints requires only subtracting the appropriate uncertainty allowances from the core DNB limit power. The uncertainty analysis to determine the Nominal Trip Setpoint (NTS) error allowances is calculated for the digital design in a manner consistent with WCAP-16361-P (Ref. 4). For these reasons, it is more appropriate to present the Safety Limits referred to in Section 2.1.1 as functions of cold leg temperature than as functions of T_{avg}.

3.0 DESCRIPTION OF DIGITAL OPΔT AND OTΔT REACTOR TRIPS

Development of the Hot Leg Temperature Signal

Current Westinghouse PWRs have three hot leg temperature signals in each T_{hot} channel, or protection system division, as does the AP1000. These three signals are generated from three locations in the hot leg piping, located approximately 120° apart around the circumference of the pipe. In some operating plants, fluid streams are extracted from these three locations, mixed hydraulically, and passed through a manifold in which RTDs measure the temperature. In other operating plants, three RTDs are placed in thermowells directly in the hot leg pipe. With either system, the hot leg temperature is based on sampling three points in the hot leg fluid stream.

In the analog OPΔT/OTΔT system, the unweighted average of these three samples is used as the hot leg temperature signal. Changes in hot leg streaming therefore affect the average. The digital design applies the following features to develop a more accurate signal that is less influenced by changes in hot leg streaming:

1. Initial filtering of each of the three locally sampled $T_{hot\text{-}local}$ signals is done to reduce process and electrical noise. The AP1000 has three hot leg RTDs and thermowells for each of the four protection divisions. The RTD and its thermowell are specified to have response times no greater than a specified value (for example, 4 seconds). This design value is assumed in the safety analysis as the sensor response time, part of the total channel response time. If plant tests demonstrate that the RTD-thermowell combination responds faster than the assigned time constant, additional filtering is applied to reduce process and electrical noise. These filters, if used, are considered part of the sensor delay and would be included in response time testing.
2. Streaming Correction: Each $T_{hot\text{-}local}$ signal is corrected so that it produces a temperature signal equal to the best estimate of the mixed mean hot leg temperature. The correction is proportional to power; that is, zero at zero power and increasing with power. The best estimate of mixed mean hot leg temperature can be determined in various ways. However, errors in determining the mixed mean temperature are not significant contributors to uncertainty in either the ΔT power signal ($q_{\Delta T}$) or the OPΔT/OTΔT setpoints.
3. Approach to Saturation: Hot leg saturation is a measurement limit rather than a core safety limit. To reduce the influence of hot leg streaming, each $T_{hot\text{-}local}$ signal is compared to saturation temperature, as computed from pressurizer pressure. If the T_{hot} signal comes within a preset margin below saturation, the signal is set to a high value that would require a trip (in that division) if confirmed by other $T_{hot\text{-}local}$ signals . (As explained in the steps below, a single $T_{hot\text{-}local}$ near saturation would be excluded from downstream calculations. If two $T_{hot\text{-}local}$ signals approach saturation, the downstream logic would go to the TRIP state.)
4. Redundant Sensor Algorithm (RSA): After initial filtering and adjusting for streaming, the three signals are compared. If each agrees with the average within a preset tolerance, all three are passed on for downstream processing. If one deviates, it is excluded from downstream processing. As noted above, if two $T_{hot\text{-}local}$ signals indicate approach to saturation temperature, the downstream channel will go to the TRIP state.
5. Weighted Average: The three $T_{hot\text{-}local}$ signals will typically have different noise and streaming characteristics. Weighting factors can be applied based on operating experience

to give higher weight to better signals. The weighting is automatically re-adjusted for the remaining two channels in the event that one $T_{hot\text{-}local}$ signal is given a BAD quality or fails the RSA check. The equation is:

$$T_H = \left[\Sigma\left(W_i T_{Hi}\right)\right] / \left[\Sigma\left(W_i\right)\right]$$, where T_{Hi} is the $T_{hot\text{-}local}$ signal from the i'th RTD (i = 1 to 3)

The individual weighting factors, W_i, are not changed when an RTD is dropped from the average. Only the sum of the weighting factors, $\Sigma(W_i)$, changes.

6. Dynamic compensation: In the analog design, lead/lags were applied to T_{avg} and ΔT to compensate for instrument delays and transient effects. In the digital design, separate lead/lag compensation is used for the T_{hot} and T_{cold} signals, providing a more accurate indication of coolant temperatures in the reactor core. The T_{hot} lead/lag compensates for fluid transit time from the reactor core to the hot leg RTD location, plus the RTD-thermowell combination and initial filter response time.

Development of the Cold Leg Temperature Signal

In the digital OPΔT/OTΔT design, the T_{cold} signal is developed in a manner similar to the T_{hot} signal, with the following differences in details.

1. Because temperature streaming is insignificant in the cold leg, only two (instead of three) $T_{cold\text{-}local}$ signals exist per division. Design provision is made for biasing the two $T_{cold\text{-}local}$ signals proportionally to power (in the same manner as for the hot leg) so that each produces a signal equal to the best estimate of the actual mixed mean cold leg temperature.
2. No check for approach to saturation is necessary.
3. In the event that the two channels deviate from each other by more than a preset amount, the RSA compares each to the expected cold leg temperature based on power and steam-line pressure. If either is within a preset tolerance of the expected temperature, then it is used for downstream calculations. If neither compares favorably with the expected temperature, then the T_{cold} signal for the division receives a BAD quality flag.
4. The T_{cold} lead/lag compensates for the RTD-thermowell combination and initial filter, minus the cold-leg-to-reactor-core fluid transit time.

Development of the ΔT Power Signal

In the analog OPΔT/OTΔT, ΔT (T_{hot} minus T_{cold}) is used as the core thermal power indication. In the digital OPΔT/OTΔT design, a more accurate power signal is generated based on the state properties of water in the hot and cold legs, and on the essentially constant volumetric flow in the cold leg. The equations for the ΔT power signal are:

$$q_{\Delta T} = f(T_H, T_C, P_{PZR})$$
$$= \rho(T_C, P_{PZR})[h(T_H, P_{PZR}) - h(T_C, P_{PZR}) - C]/\Delta T^{\circ}$$

where:

T_C = $(1 + \tau_1 s)/[(1 + \tau_2 s)(1 + \tau_3 s)]T_{cold}$, where T_{cold} is the measured cold leg temperature (lead/lag compensation with time constants τ_1, τ_2, and τ_3 applied to compensate for the RTD-thermowell combination and initial filter response time, minus cold-leg-to-core fluid-transport time)

T_H = $(1 + \tau_4 s)/[(1 + \tau_5 s)(1 + \tau_6 s)]T_{hot}$, where T_{hot} is the measured hot leg temperature (lead/lag compensation applied with time constants τ_4, τ_5, and τ_6 to compensate for the RTD-thermowell combination and initial filter response time, plus core-to-hot-leg fluid-transport time)

A second-order lag is used for T_C and T_H for additional filtering of high frequency noise such as electrical interference.

$\rho(T_C, P_{PZR})$ = density of water at cold leg temperature T_C and pressurizer pressure P_{PZR}

$h(T, P_{PZR})$ = enthalpy of water at the specified temperature (T_H or T_C) and pressurizer pressure P_{PZR}

$\Delta T°$ = a conversion factor, so that the value of $q_{\Delta T}$ is 100 percent at normal rated thermal power

C = A bias coefficient that permits zeroing $q_{\Delta T}$ at zero power (to compensate for small errors in RTD calibration)

The design intent is that the ΔT power signal, $q_{\Delta T}$, be frequently compared to the measured calorimetric power and adjusted as necessary (by adjusting the ΔT° value), similar to standard practice for calibrating the power range neutron flux signal to be equal to the measured calorimetric power. In the AP1000, the reactor operator will have the capability to adjust (calibrate) the ΔT power signal continuously available via the Safety Displays in each division. This is the same design provision that is being made for adjustment of the neutron flux power range signal.

Development of the Digital OPΔT Setpoint

The setpoint for the digital overpower trip is continuously calculated with correction (if needed) for adverse axial power distribution.

$$OP\Delta T_{SP} = C_{OP}° - f_2(\Delta I),$$

where:

$C_{OP}°$ = A preset bias, equivalent to K_4 in the analog OPΔT (Ref. 1)

$f_2(\Delta I)$ = A function of the neutron flux difference between upper and lower ionization chamber flux signals (to reduce allowable core power, if necessary, because of an adverse axial flux shape)

Increases in ΔI beyond a predefined deadband result in a decrease in the trip setpoint.

Development of the Digital OPΔT Margin to Trip

With digital technology, a separate "margin to trip" signal can be generated without increasing either errors or time delays. This permits lead/lag compensation to be put on the "margin to trip" signal to compensate for reactor trip delays (such as for instrument processing, breaker opening, control rod gripper release, and any time necessary for control rod negative reactivity insertion to reduce power).

A reactor trip is initiated if the OPΔT margin to trip becomes negative (ΔT power signal, $q_{\Delta T}$, exceeds the setpoint) in two of the four divisions; that is:

$$\text{Margin}_{OP\Delta T} = [OP\Delta T_{SP} - q_{\Delta T}]\,(1 + \tau_7 s)/[(1 + \tau_8 s)(1 + \tau_9 s)]$$

where:

τ_7, τ_8, τ_9 = Lead and lag setpoints provided to compensate, if necessary, for protection-system and control rod insertion delays in reducing core power

A second-order lag is used for additional filtering of high frequency noise such as electrical interference.

In addition to being the input to the reactor trip bistable, the $\text{Margin}_{OP\Delta T}$ signal is made available to the non-safety related plant control system to provide displays and alarms in the main control room as well as for use in plant control functions.

Development of the Digital OTΔT Setpoint

The setpoint for the overtemperature trip is continuously calculated, with one set of temperature measurements per loop, by interpolating from tabulated core safety limits, with correction (if needed) for adverse axial power distribution:

$$OT\Delta T_{SP} = OT\Delta T^{\circ}_{SP} - f_1(\Delta I)$$

where:

$f_1(\Delta I)$ = A function of the neutron flux difference between upper and lower ionization chamber flux signals (to reduce allowable core power, if necessary, because of an adverse axial flux shape). The source of neutron flux information for $f_1(\Delta I)$ is identical to that for the OPΔT trip.

$OT\Delta T^{\circ}_{SP}$ = The core DNB thermal design limit with design axial power distribution, determined by interpolation from specified tables of allowable core thermal power as a function of pressurizer pressure and core inlet temperature, or $f(P_P, T_C)$

P_P = Minimum of $[P_{PZR}\,(1 + \tau_{21} s)/(1 + \tau_{22} s)$ and $P_{PZR}]$. The pressure signal, P_P, is the minimum of the pressurizer pressure signal, P_{PZR}, with and without lead/lag compensation (time constants τ_{21} and τ_{22}). This adjustment compensates for reactor trip delays if pressure is decreasing, but retains conservatism if pressure is increasing.

T_C = The same signal for core-inlet temperature as used in generating the ΔT power signal, $q_{\Delta T}$; that is, the measured cold leg temperature with lead/lag compensation

Development of the Digital OTΔT Margin to Trip

As with the digital OPΔT trip, a reactor trip is initiated if the OTΔT margin to trip, including lead/lag compensation, becomes negative (ΔT power signal, $q_{\Delta T}$, exceeds the setpoint) in two of the four divisions; that is,

$$\text{Margin}_{OT\Delta T} = [OT\Delta T_{SP} - q_{\Delta T}]\ (1 + \tau_{10}s)/[(1 + \tau_{11}s)(1+\tau_{12}s)]$$

where:

τ_{10}, τ_{11}, τ_{12} = Lead and lag setpoints provided to compensate, if necessary, for protection-system and control rod insertion delays in reducing core power

A second-order lag is used for additional filtering of high frequency noise such as electrical interference.

4.0 DIGITAL OPΔT/OTΔT SETPOINTS IN COLR (CORE OPERATING LIMITS REPORT)

The digital OPΔT/OTΔT setpoint values prescribed in the COLR are identified below, with "≥" or "≤" or "=" symbols as appropriate. These setpoint values are the values used in the safety analysis of record, as described in Section 5 of Ref. 2, reduced by an uncertainty allowance (Ref. 4) where appropriate.

ΔT Power Signal

The only COLR setpoints in the ΔT power signal generation are the time constants for dynamic compensation of the T_{cold} signal (τ_1, τ_2, and τ_3) and the T_{hot} signal (τ_4, τ_5, and τ_6). These time constants do not have a "conservative" direction. Larger (or smaller) values will be conservative for some events and non-conservative for other events. Therefore, they are to be set equal to the values used in the safety analyses.

Time constants: $\tau_1 = SA^{(1)}$, $\tau_2 = SA^{(1)}$, $\tau_3 = SA^{(1)}$, $\tau_4 = SA^{(1)}$, $\tau_5 = SA^{(1)}$, and $\tau_6 = SA^{(1)}$.

Digital OPΔT Trip

$C_{OP}^{o} \leq SA^{(2)}$ C_{OP}^{o} is equivalent to the K_4 term for the analog OPΔT trip (Ref. 1).

$f_2(\Delta I)^{(3)}$

Time constants on margin to digital OPΔT trip: $\tau_7 \geq SA^{(1)}$, $\tau_8 \leq SA^{(1)}$, $\tau_9 \leq SA^{(1)}$

Digital OTΔT Trip

Input table of allowable power versus core T_{inlet} at various pressures$^{(2)}$ as discussed in Section 2.

$f_1(\Delta I)^{(3)}$

Time constants for pressurizer pressure: $\tau_{21} \geq SA^{(1)}$, $\tau_{22} \leq SA^{(1)}$,

Time constants on margin to digital OTΔT trip: $\tau_{10} \geq SA^{(1)}$, $\tau_{11} \leq SA^{(1)}$, $\tau_{12} \leq SA^{(1)}$,

Notes:

(1) SA refers to the limiting values used in the safety analysis of record. The lead and lag values must equal the values used in the limiting safety analyses for these time constants. (Analyses of some events may conservatively neglect lead/lag compensation.)

(2) These setpoints are more restrictive than the safety analysis values in terms because they include uncertainty allowances.

(3) The definitions for $f_1(\Delta I)$ and $f_2(\Delta I)$ are identical to current Technical Specification definitions. There is no change in their basis or the methodology for calculating them from the practice with the analog OPΔT/OTΔT.

5.0 REFERENCES

1. WCAP-8745-P-A, "Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions," September 1986.
2. WCAP-9272-P-A, "Westinghouse Reload Safety Evaluation Methodology," July 1985.
3. AP1000 Design Control Document, Revision 18.
4. WCAP-16361-P, "Westinghouse Setpoint Methodology for Protection Systems – AP1000," May 2006.
5. American National Standards Institute N18.2, "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants," 1973.